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TYPE N STREAM DEMARCATION STUDY PHASE I: PILOT RESULTS

Final Report

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EXECUTIVE SUMMARY

Non-fish bearing (Type N) streams are divided into seasonal (Type Ns) and perennial (Type Np) portions. Because forest practice regulations differ substantially between Np and Ns segments, an accurate estimate of the Np/Ns break is desirable.

The Type N Demarcation Study is intended to gather data to "refine the demarcation of perennial and seasonal Type N streams," a task identified in Schedule L-1 of the Forest & Fish Report (FFR). The pilot phase was designed to:

- Test the adequacy and replicability of the pilot field protocol for identifying the Np/Ns break
- Estimate the size and variability of basin areas and other parameters
- Evaluate the potential for using basin and channel attributes to determine the Np/Ns break in the field

This information was collected for use in the larger statewide study envisioned to follow.

Ten cooperators (seven tribal, one state agency, and two timber industry) collected field data at a total of 218 Type N streams. Fifteen study areas were chosen by cooperators and included nine located on the westside (one partially within the Coastal spruce zone) and six on the eastside of the Cascade Crest. Within each study area, sites were selected either randomly or to revisit sites from past surveys. Data were collected during summer low flow conditions in 2001. At each study stream, field surveys documented the flow categories in each segment of 30 meters (~100 feet) or shorter. At each segment break channel width, depth, gradient, substrate, and associated features were recorded. The field data were subsequently analyzed to determine the location of three hydrologic transition points:

- Ch – the channel head
- Pd – the highest observed perennial water (may be continuous or discontinuous, flowing or standing). Pd is the regulatory Ns/Np break.
- Pc – the upper end of continuous perennial flow.

The basin divide upstream from each Pd, Pc and Ch was delineated on USGS topographic maps by a single technician for consistency and the area determined.

The statistical analysis summarized the field data, determined basin areas and variance, and alternative indicators of the Np/Ns break. All data distributions follow a lognormal distribution and appropriate transformations were used for statistical testing.

The key results of the pilot study are:

1. The pilot protocol is adequate for collecting observed field conditions associated with perennial flow. Minor adjustments and additions may be necessary; the most important is the inclusion of the channel head in all future surveys.

2. Observed basin areas are smaller than the FFR default basin areas. Median observed basin areas above the Np/Ns break (Pd) for the Eastside, Westside, and Coastal FFR default regions are 36, 7, and 2 acres, which are less than 15 percent of the FFR default basin area, and the average observed basin areas are 118, 24, and 8 acres, which are less than 61 percent of the FFR default basin areas. (Comparison of observed basin areas to default basin areas is complicated by uncertainty over the whether the default values represent averages, medians, or some uncalculated and negotiated value).

3. Considerable variability was observed among basin areas. Observed basin areas differ significantly between FFR default regions and between ecoregions. Average annual precipitation classes appear to provide a better means of stratification than either present default regions or ecoregions.

4. No physical channel characteristics were found to be reliable field indicators of the Np/Ns break. However, distance down slope from the basin divide or distance downstream from channel head may prove to be acceptable predictors or default criteria.

5. The sample size required to estimate the average basin area with a 90% confidence interval and 10% precision depends on the stratification criteria. Assuming three cells (e.g. Eastside, Westside, Coastal) within the strata (e.g. FFR default regions or precipitation classes), the present FFR default regions and proposed precipitation class default regions require a minimum sample of 300 sites whereas, the use of distance downstream from divide to Pd as an alternative default criterion, requires a minimum sample of 30 sites.

If a statewide demarcation study with similar research objectives is pursued, insights from the 2001 pilot study support the following:

1. Utilize a field protocol similar to that used in 2001 with minor changes to include the channel head, debris-flow categories, and valley width.
2. Stratify by average annual precipitation categories that would extend across the state.
3. Provide "equal probability" sampling from the population of N streams within each stratum.
4. Assess the adequacy of using other metrics as default criteria, e.g., distance from divide or annual precipitation.
5. Select a sample size that will provide the desired precision level.

Expansion or modification of the scope of future studies beyond the demarcation focus of the pilot phase (e.g. in-channel habitat and functions) is feasible but will likely require additional changes to sampling approaches and field protocols.

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SECTION 1. INTRODUCTION TO REPORT

This document presents the results and recommendations of the Type N Stream Demarcation Pilot Study conducted by the Np Technical Group for the Cooperative Monitoring, Evaluation, and Research Committee (CMER) of Timber, Fish, and Wildlife (TFW). It is the first phase of a planned two-phase demarcation study to collect data to "refine the demarcation between perennial and seasonal Type N streams" (Forest & Fish Report, Schedule L-1).

The pilot study began as an effort to develop a field protocol and to test its adequacy while collecting sufficient data on basin area variability to determine a sample size for the following phase of the study. During the development of the scope of work for the pilot study, a set of hypotheses was developed to explore the ramifications of the data. The relative importance of the two aspects of the pilot study changed during the testing of these hypotheses. Preliminary findings indicated the observed basin areas were significantly smaller than anticipated, which lead to the conclusion that a separate paper for submission to a technical journal was required to more fully develop these aspects of the study.

STUDY BACKGROUND

Forests and Fish

The Forests and Fish Report (FFR) establishes a water typing system that identifies headwater streams, which do not contain fish habitat, as "Type N" waters (**Table 1**). Type N waters are further subdivided into two categories:

- Perennial ("Np") segments that do not go dry (including "spatially intermittent" channels that contain short alternating wet and dry reaches); and
- Seasonal ("Ns") segments that go dry "in a year of normal rainfall" and are located upstream of the perennial reaches.

These definitions (**Appendix A**) are in Chapter 222-16-030(3) and (4) in the Washington Administrative Codes (WAC). The FFR definition is unclear about the flow conditions necessary to qualify as an "Np" stream, e.g. continuous or discontinuous bodies of water, flowing or standing, open or piped channels.

Table 1: **FFR stream types**.

Type	Description
S	All waters within their ordinary high water marks inventoried as "Shorelines of the state."
F	All segments of natural water within bankfull widths containing habitat used by fish at any life stage and at any time of year.
N	All water that are not S or F that are either perennial or connected by an above ground channel to waters connected to F or S streams.
Np	Perennial: Type N waters that do not go dry at any time during "a year with normal rainfall."
Ns	Seasonal: Type N water that goes dry during " a year with normal rainfall."

The distinction between Type Np and Ns streams is important to rule implementation. Type Np streams are believed to provide habitat necessary to support the long-term viability of state-protected amphibians and water conditions that support harvestable levels of salmonids in downstream Type F (fish-bearing) streams (Gomi and others, 2002; Meyer and Wallace, 2001; May and Gresswell, 2003). For these reasons, the riparian areas along Type Np streams are given specific protections during forest practices (logging, road maintenance) that are not required for Type Ns streams.

Identifying the change from seasonal (Ns) to perennial (Np) waters, the Np/Ns break, is difficult except during the late summer-early fall, low-flow season. The following quote from the FFR Appendix B, 2 (iii) describes the anticipated problem of field identification and provides for an interim solution.

"*Making the determination [of the initiation point of perennial Type N waters] will require a better understanding of the natural variability of the spatially intermittent component of perennial streams. Factors such as stream associated amphibian habitat, sediment deposition patterns, channel morphology, water flow, non-migrating seeps or springs, and position in the basin will be observed in preparing a protocol for perennial stream identification. In those cases where non-migrating seeps or springs as the point of initiation of perennial flow cannot be firmly identified with simple, non-technical observations: (A) on the Westside, Type N waters will be "perennial streams" if they have a basin size in excess of the following minimums: 13 acres in the coastal zone … and 52 acres on the rest of the Westside; and (B) on the Eastside, Type N waters will be "perennial streams" if they have a basin size in excess of 300 acres*."

The extent to which field identification vs. basin area defaults are used as the regulatory water typing method is unknown.

The basin area defaults were developed from limited, unpublished field data collected by volunteers during the Forest and Fish negotiations in 1998. Some of the pre-2001 studies are summarized in **Appendix B** (Pre-2001 Studies) and their results presented in **Table 2**. Of the data discussed during the 1998 rule negotiations, only the Kapowsin data were documented. Therefore, the default basin area does not reflect the numbers in **Table 2**. The FFR authors recognized the scientific uncertainty underlying the selected default basin areas by placing this study in Schedule L-1 of the FFR.

Table 2:**Previous Studies**. Results of pre-2001 field studies to assess default basin areas. Of these only the preliminary Kapowsin data were available during the 1998 FFR negotiations. See summary report in **Appendix B**.

Study Area	Basin Areas (acres)	
	Average	Median
Kapowsin	41	17
SW Washington	20	13
Mid-Columbia	90	32
Chelan	68	39
Stillman Basin	11	10
Skagit	23	17

CMER, which is responsible for assessing the effectiveness of the rules, identified this issue as a top priority for adaptive management efforts and approved funding the project in fiscal year 2001. The Upslope Processes Scientific Advisory Group (UPSAG) is responsible for managing the project and established the *ad hoc* “Np Technical Group” in June 2001 to manage the process and provide technical guidance.

Study Development

The Np Technical Group developed a pilot study protocol (Perennial Stream Survey Field Sample Protocol, version 1.21) to guide data collection during the August to October 2001 field season. The ten CMER cooperators listed in **Table 3** collected field data using the pilot study protocol from a total of 224 headwater basins in both Eastside (300 acres) and Westside (52 acres) FFR default basin regions (**Figure 1**). The Coastal FFR default region (13 acres) was not specifically targeted during the pilot study but one Westside study area includes the boundary with the Coastal default region and was placed in that region to estimate its parameters. Coordinated training and quality control/assurance

(QA/QC) programs were implemented on a limited basis because of time limitations.

Table 3: **Cooperators** collecting field data for the 2001 Type N Demarcation Study by code, name, and number of study sites provided for the data analysis. Study areas are located in Figure 1.

Code	Cooperator	Number of Sites
TCG	The Campbell Group	61
COL	Colville Confederated Tribes	13
HOH	Hoh Tribe	22
LVF	Longview Fibre Co.	40
PGS	Prot Gamble S'Klallam Tribe	4
SCC	Skagit System Cooperative	25
SPO	Spokane Tribe	6
SUQ	Suquamish Tribe	6
DFW	Washington Department of Fish and Wildlife	34
YAK	Yakama Nation	13
	Total Number of Study Sites	**224**

An analytical protocol was developed during the fall and winter of 2001 and collation and analysis of the field data began in February 2002. The purpose of the analytical phase was to evaluate the 2001 pilot study protocol and the 2001 field data.

PILOT STUDY PURPOSE

The dual purposes of the pilot study are (a) to test a field protocol for collecting water-typing data on the initiation of perennial flow and (b) to collect sufficient water-typing data to assess its variability for use in the design of a statewide data collection effort envisioned to follow this pilot study. The objectives that achieve these purposes are listed in **Table 4.**

ASSUMPTIONS AND DEFINITIONS

A few key definitions and assumptions are necessary to assess Type N flow regimes and basin areas. Type N portions of streams are found above the uppermost extent of fish habitat, as defined in WAC 222-16-030(2) for Type F waters, and extend upstream to the channel head (**Figure 2**). As such, they are usually the smallest streams with few or no tributaries.

Table 4: **Objectives** of the Type N Stream Demarcation Study: pilot Phase.

Objectives of the 2001 Pilot Study
1. Develop pilot field and analytical protocols for the collection and analysis of field observations.
2. To assess the: • Adequacy and replicability of the pilot protocol. • Variability of basin areas and other parameters. • Basin and channel attributes that are potentially useful in defining the Np/Ns break. • Refine protocols for the statewide study.

Definitions

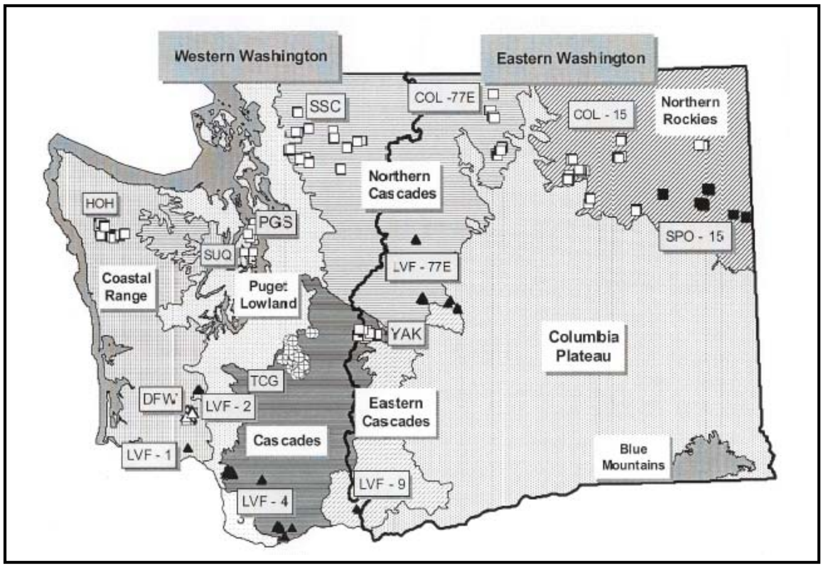

Figure 1: Location of study areas and USEPA Level III Ecoregions in Washington. The 15 study areas are identified by cooperator code (Table 3) and by ecoregion number. The heavy north-south line is the Cascade crest; it divides the state into Eastern Washington (Eastside) and Western Washington (Westside) FFR default regions. The Coastal spruce zone FFR default region is not shown but occurs as a band along the Pacific coast.

Hydrologic Points

The demarcation study includes three key hydrologic points that break flow conditions within a headwater stream (**Figure 2**):

Ch: The channel head is the highest observed point of channel incision or scour that separates unmodified forest floor from the channel. Ch marks the headward extent of flowing surface water with sufficient energy to erode a channel into surficial materials (Horton, 1945; Dunne, 1980). The pilot phase did not require cooperators to collect Ch data.

Pd: The highest observed point of perennial water (may be continuous or spatially intermittent [discontinuous], flowing or standing). The Pd is also the lowermost point of the continuously dry, seasonal (Type Ns) channel downstream from the channel head. Pd marks the headward extent of seepage in sufficient quantities to maintain storage in alluvium, dry season evapotranspiration, and bodies surface water (Clement, and others, 2003).

Pc: The highest observed point of continuous perennial water (may be flowing or standing). Pc was verified by a downstream survey to either the junction with Type F waters, or 200 meters whichever came first. Pc marks the headward extent of sufficient groundwater recharge to the channel to maintain continuous surface flow.

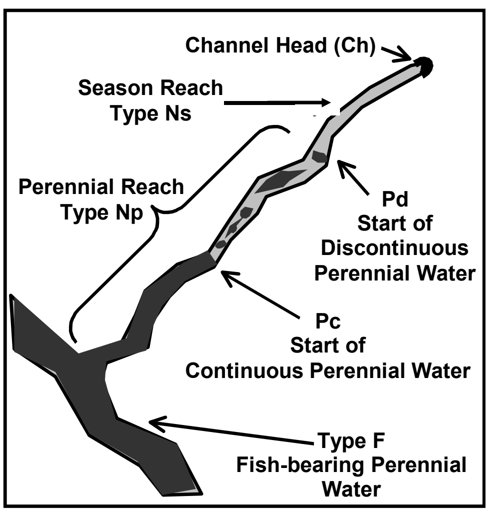

Figure 2: FFR water types and hydrologic points. The FFR water types are based on the distribution of fish habitat (Table 1). The hydrologic points define the limits of the seasonal and perennial water types.

Channel Terms

The hydrologic points divide the channel into three reaches including one or more segments (**Figure 2**).

Reach: A portion of the channel having similar hydrologic characteristics. The reaches used in this report include:

Seasonal: The headward portion of the channel that goes dry during years of normal rainfall. It occurs between hydrologic points Ch and Pd. Also known as intermittent or Type Ns stream.

Discontinuous Perennial: The headward portion of the channel that contains small (~5 cm) to large bodies of standing or flowing water throughout the year. It occurs between hydrologic points Pd and Pc and is Type Np waters.

Continuous Perennial: The portion of the channel that contains a mostly continuous body of flowing or standing water. It may contain dry segments as long as five meters (~16 feet) and occurs downstream of hydrologic point Pc and is Type Np waters.

Segment: A portion of the channel with similar flow characteristics identified during the pilot survey for purposes of description. Segment breaks occur at a change in flow characteristics or every 30 meters (98 feet) whichever is less.

Drainage Basin Terms

Drainage Basin: The area that contributes water to a selected portion of a stream network (**Figure 3**). The term may refer to either surface water (watershed) or to subsurface water (soil and/or ground water). It is separated from adjacent drainage basins by the stream divide.

Stream Divide (Divide): The line of highest elevation on the land surface between adjacent drainage basins that separates surface water flowing toward one stream from that flowing toward the adjacent stream.

Subsurface Divide: The line of highest elevation on the top of the saturated zone between adjacent subsurface drainage basins that separates soil and/or groundwater flowing toward one stream from that flowing toward the

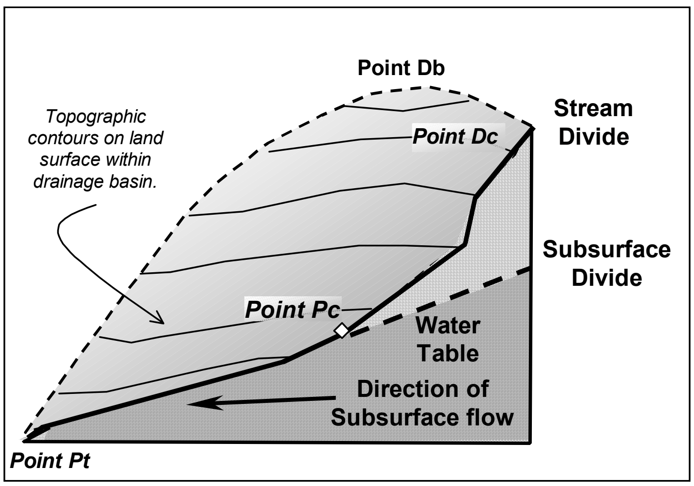

Figure 3: Block diagram showing the assumed relationship between surface and subsurface drainage basins. The subsurface divides are assumed to coincide with the surface divide with the subsurface water discharging to the stream to maintain perennial flow. The water table is shown intersecting the channel bed at Pc (the beginning of continuous perennial flow) but it may intersect the channel bed farther upstream at Pd (beginning of discontinuous perennial flow), which is not shown.

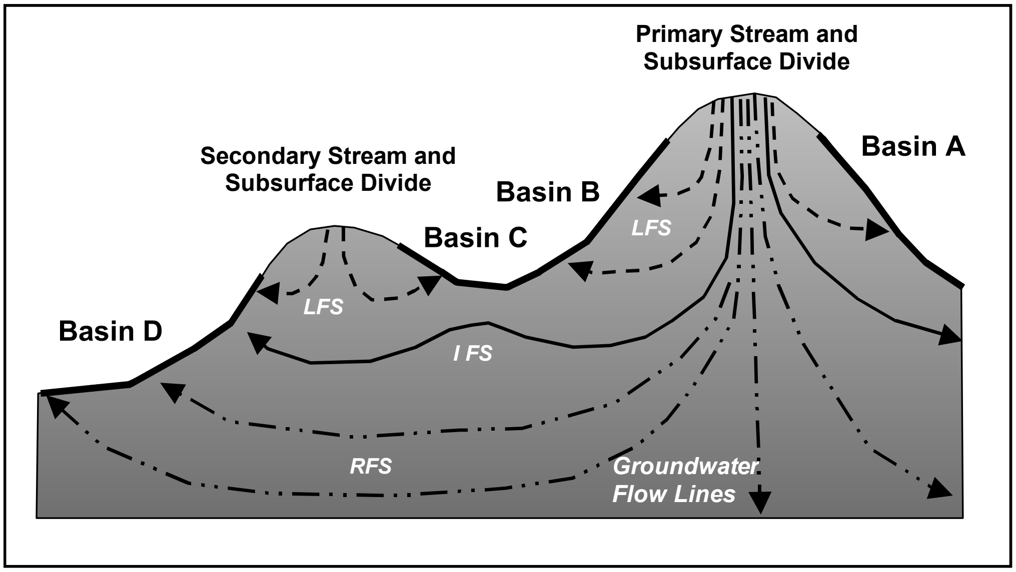

Figure 4: Groundwater flow regimens. A large dissected upland between two major rivers may support a complex groundwater flow system consisting of local flow systems (LFS) between hillslope and adjacent tributary stream [Basins B and C]; the intermediate flow systems (IFS) that may extend under local divides to discharge into a distant tributary stream [Basin D]; and the regional flow system (RFS) that extends from the major divide to the major stream [Basin D] and passes under local and intermediate divides.

adjacent stream. It may or may not coincide with the stream divide.

Assumptions

Drainage Basin Assumption

An implicit assumption underlying the use of basin area defaults in the FFR rules and this study is that for any perennial stream the subsurface divide and stream divide coincide. The drainage basin assumption allows the use of topographically defined default drainage basin areas to estimate the location of the Np/Ns break, which is probably controlled by discharge of subsurface water to the channel. Numerous studies have shown that drainage basin area is an important hydrologic control on perennial flow although other factors must also be considered (Smakhtin, 2001).

The drainage basin assumption may be reasonable for drainage basins located near primary drainage divides from which the land slopes away in both directions toward major streams. In these locations, the potential for subsurface inflow under the divide is probably low. However, the drainage basin assumption may not apply to all drainage basins (Freer and others, 1997). For instance, drainage basins located lower in the landscape where the potential for groundwater inflow along a variety of routes from areas higher than the secondary divides is possible (Winter, 1999). These relationships are shown schematically in **Figure 4**.

Where subsurface inflow to channels occurs at springs and seeps the location of points Pd and Pc are controlled by these features and their seasonal migration inhibited. Some of these springs and seeps may be discharging groundwater that has flowed under the surface divide from upslope drainage basins. The measured drainage basin areas were classified as "controlled" where Pd or Pc was located at or near (within two meters) observed springs, seeps, wetlands or the channel head (Ch).

Basin Delineation Assumptions

Two assumptions are necessary to determine and outline the boundaries of drainage basins on a topographic map – the topographic assumption and the symmetric basin assumption. To the extent that these assumptions do not apply to the surveys within a study area, the statistical variability in basin areas and distances downstream increase for that study area.

Topographic Assumption

The topographic assumption is that the topographic map accurately displays the location of stream channel and drainage divides in the vicinity of the study site. This assumption is necessary when using USGS topographic maps and digital elevation models (DEMs) as base maps on which to locate points and delineate basin divides.

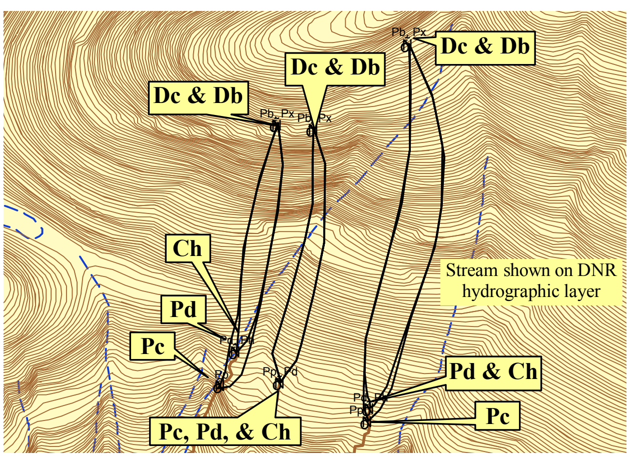

Figure 5a: Site showing discordance between low relief valleys and USGS 7.5 minute topographic maps. The basin divides for Ch, Pd, and Pd as mapped by the cooperator using field and aerial photographic information. The mapped divides and streams do not agree with the contours on this DEM map of a portion of the Skagit River Valley (SSC 105 A, B, and C)

The topographic assumption may not be valid for small streams that are unconfined, in valleys of low relief, and/or under a dense forest canopy (Meyer and Wallace, 2001). When the relief is too low to cause an undulation in the forest canopy, either the channel location and/or divides may not appear on the topographic map or their location, continuity, or configuration may be inaccurate. An example of this problem for a small, shallow valley on extensive side slopes of the Skagit River Valley is shown in **Figure 5a**.

The symmetric basin assumption is that the drainage divides above points Ch, Pd, or Pc extend upslope perpendicular to the contour lines on both sides of the valley as shown in **Figure 5b**. The symmetric-basin assumption is not valid when the stream heads in a valley-side seep or spring. In this case, the drainage basin extends toward the divide on only one side of the valley.

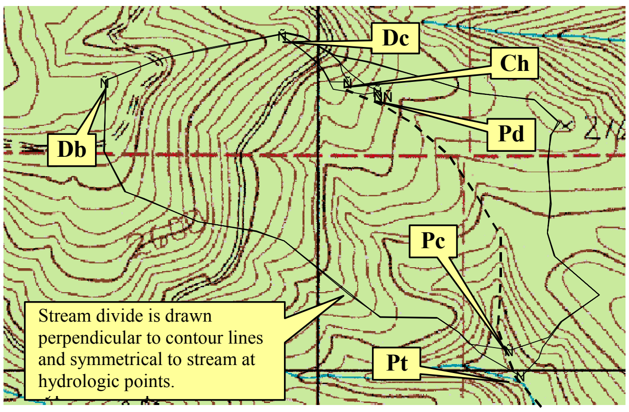

Figure 5b: Symmetric basin assumption. The stream divide for this study site in the Stillman Basin (DFW 44) is strongly defined in the high relief areas around Pc and Pt and weakly defined in the low relief valley around Pd and Ch. In both cases the symmetric basin assumption was used to draw the divide from the hydrologic points along the stream toward the ridge crests. Pt is the junction between basins visually estimated to have the same order.

Year of Normal Rainfall

Perennial Type N streams are defined in FFR as those that "do not go dry in a year of normal rainfall," though no definition of "normal rainfall" is provided. The precipitation for the 2001 water year (October 2000 through September 2001) can only be approximated for the study areas because of the lack of in area meteorological stations. Based on the closest meteorological stations the 2001 water year precipitation is estimated to be around 85 inches for study sites in the Coastal region, 30 to 40 inches for most sites in the Westside and 8 to 15 inches for most sites on the Eastside. Westside and Eastside study areas located in the Cascade Range received more precipitation, around 50 to 60 inches. The pilot-study data must be evaluated with respect to "a year of normal rainfall" and interpreted accordingly. The analysis of the 2001 water year, which is presented in the Results section, indicates that the water year was unusually dry but that the summer months on the Westside were unusually wet.

POTENTIAL CONTROLS ON BASIN AREAS

Perennial waters require sufficient subsurface storage capacity to deliver water to streams for the duration of the dry season (Asano and others, 2002; Smakhtin, 2001). In simple terms, this requires the subsurface reservoir (drainage basin) to

- Be sufficiently large (area, thickness)
- Contain suitably porous soils
- Drain subsurface water at a rate that maintains seepage to channels between rainfalls during the dry season

Five surrogates for these properties are used to estimate reservoir conditions. These are shown in **Figure 6** and defined below:

- Drainage basin area - the surrogate for water volume;

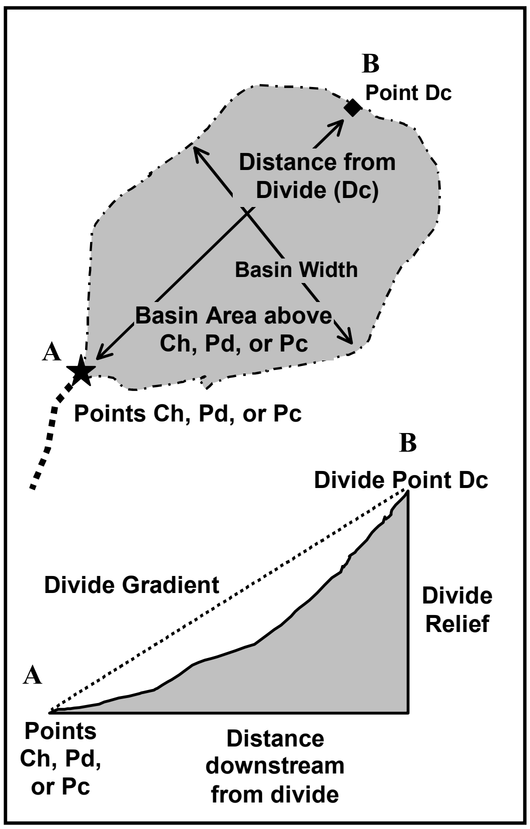

Figure 6: Site variables. Variables used to estimate the size of the subsurface reservoir maintaining perennial flow.

- Distance - as measured perpendicular to the topographic contours between point Pd and the divide (point "Dc") – a measure of reservoir length;
- Basin Width – the mean measure of reservoir width as estimated by dividing basin area by Pd distance downstream (half width estimates the average length of hillslopes in basin);
- Basin relief - a surrogate for the energy gradient driving subsurface water toward point Pd, and surface water flow downstream from it. It has two components: basin relief, which extends to the highest point on the divide (point "Db"), and divide relief, which extends to Dc,

the point where the stream trace intersects the divide; and

- Geology/soils – a measure of reservoir porosity and permeability. Geology and soils were not included in this phase of the study.

SECTION 2. METHODS

Field Data

Field data were collected following procedures (**Table 5**) in the pilot study protocol (**Appendix C**). Training and field assistance services were provided to tribal cooperators, other cooperators if requested, through the Northwest Indian Fisheries Commission (NWIFC). These services were designed to reduce potential variability in data collection and to identify the parts of the protocol producing the most problems. Time constraints precluded comprehensive protocol training for all cooperators.

Task	Procedure	Discussion
Sample Site Selection	Identify Type F/N breaks within study area; number breaks and select using a random number generator	Study sites are limited to lands managed under Forest Practice Rules. Other options to randomly select stream segments are available.
Identifying Survey Starting Point	Select a point on the sample stream with continuous perennial flow to mouth or where at least 200 m of continuous flow is visible. Select an easily identifiable point, such as a culvert, and survey upstream from this point.	Survey may be conducted in an upstream or downstream direction. Upstream is preferred direction.
Survey route (Selecting Tributaries)	In the Main Thread Survey, select the tributary with either the highest flow category or the highest channel category (see definitions in Appendix B). When tributaries are identical, flip a coin to select right or left tributary and alternate tributaries in further cases.	Two survey types possible – Main Thread and Total Tributary. In main thread only one channel is followed to head, In Total Tributary all tributaries upstream from the Type F/N break are surveyed.
Channel Segment Identification	New channel segments begin at changes in flow category, confluence with a tributary, or 30 meters, which ever is shortest.	At each change in channel segment, data on segment length and channel geometry and characteristics are recorded for the segment just surveyed. Features to be recorder are listed in Appendix B.
End Point Determination	Survey ends after 200 m of dry channel or the channel head are encountered.	Surveys were not required to continue to the channel head or to record the channel head if it was encountered.
QA/QC	Repeat surveys at different times, or with different crews, and by continuing to head of channel	Three survey components tested: 200 m distance, flow changes within sample period, and between crew variability

Table 5: Summary of the 2001 pilot protocol. The complete protocol appears in Appendix C.

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Study Site Selection

Cooperators were free to choose one or more study areas according to their own selection criteria. Within each study area, the sites were randomly selected using the following procedure; the streams are numbered at one of the following locations:

1. Confluence between Type F and Type N streams
2. Intersection between streams and section boundaries

3. Confluence of second order streams
4. Previous stream surveys

Then, streams were selected using a random number generator. A few study sites were selected as being representative of the area and some were revisited basins from previous studies.

Survey and Segment Description

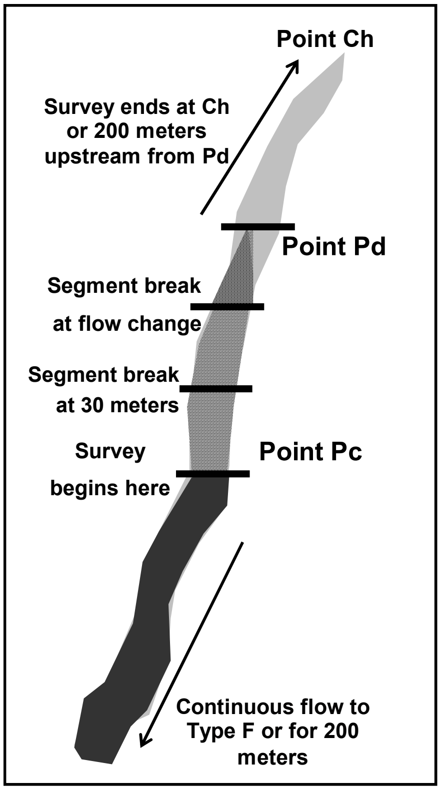


Figure 7: Survey reference points. Type N stream showing the requirements for survey end points and segment breaks at 30 meters or change in flow category.

The intent of the survey was to identify points Pd and Pc and to describe the channel reach between them. To meet this intent, the survey was to extend 200 meters (565 feet) upstream from the highest observed point of perennial water (Pd), either spatially discontinuous or continuous flow, and 200 meters (565 feet) downstream from the highest point of continuous perennial flow (Pc) to ensure that both points Pd and Pc were included within the data set (**Figure 7**). The stream channel within the survey was subdivided into a series of segments for data collection and analysis. Segments were 30 meters long (~100 feet) unless a change in flow category (**Table 6**) reduced that length.

Segment Observations

At each segment break, the field observations were recorded on the field data sheets (**Appendix C**). The geomorphic and hydrologic data collected for each segment are listed in **Tables 6** and **7** and described in **Appendix D**.

Segment data were collected using reconnaissance-level procedures that would be similar to those used by practicing foresters searching for Pd:

- Bankfull width and depth were measured at one or two representative channel cross sections within a segment using a fiberglass tape, stadia rod or other common measuring devise.

- Segment gradient was measured at the segment break by upstream and downstream shots using a clinometer or by laser rangefinder from one segment break to the next.
- Dominant substrate was visually estimated for the segment.
- Geomorphic features that could affect the segment hydrology were visually identified (**Table 7**).

Table 6: **Segment Data**. Descriptive data required for each segment in a survey. Data are to be recorded at a segment break for the segment just completed.

Flow Category	
Flowing Water (FW)	Dry (D)
Standing Water (SW)	Unknown (U)
Flowing Pocket Water (FP)	Obscure (O)
Standing Pocket Water (SW)	
Channel Category	
Defined Channel (DC)	Piped Channel (PC)
Poorly Defined Channel (PDC)	No Channel (NC)
Modified Channel (MC)	
Channel Geometry	
Bankfull Width (BFW)	Upstream Gradient (%)
Bankfull Depth (BFD)	Downstream Gradient (%)
	Mean Segment Gradient (%)
Dominant Substrate	
Fine-grained [silt/muck/mud] (F)	Cobble (C)
Sand (S)	Boulder (B)
Gravel (G)	Bedrock (R)
Associated Features	
See Table 7	
Tributary Changes	
Record Flow and Channel categories	

Table 7: Associated Features. List of features that could occur at flow-change segment breaks and be a potential cause of the flow change.

Spring (SP)	Gradient Break (GB)
Seep (SE)	Debris Slide (DS)
Wetland (WT)	Substrate Change (SC)
Wet Site (WS)	Road Crossing (RC)
Beaver Pond (BP)	Road Drainage Input (RD)
Perennial Tributary Junction (PJ)	Diversion (DI)
	Other (OT)

Data Submission

To insure uniform and consistent data entry, the field data were recorded, collated, and submitted on 2001 Data Entry Forms (**Appendix E**) following the definitions in the 2001 Data Dictionary (**Appendix D**).

GIS Data

Topographic and environmental data for each study site were extracted from GIS using ArcInfo and ArcView. GIS data were provided by:

- Cooperators -- point locations and some basin area delineations;
- The Washington Department of Natural Resources-- Data layers listed **Table 8**; and
- CMER staff geomorphologist – located additional points and delineated most stream divides in the ArcView format.

Table 8: GIS data layers used to describe site characteristics.

GIS Layer	Description
USGS Topographic Maps	Scanned and georeferenced 1:24,000 topographic quadrangles; served as base maps for locating field points and measuring areas and distances.
DEM Data	Digital elevation models of the topographic maps at a 10-meter resolution. Used to determine elevation of points.
EPA Ecoregions	EPA Level III Ecoregions; used as a stratum for classifying site locations.
PRISM Precipitation Layer	Estimated average annual precipitation at points within survey sites.
DNR Stream Layer	Streams digitized from USGS topographic maps and aerial photographs and identified by a unique number.
DNR Soils Layer	Forest soil map interpreted for texture and used to categorize sites.
DNR Geology Layer	Digitized geology map of state at 1:100,000 that was interpreted for lithology and used to categorize sites.

GIS Procedures

The GIS portion of the analysis occurred in four steps:

1. ***Point Plotting***: Coordinates for Pd, Pc, and Ch were provided by cooperators and transformed to UTM coordinate system by Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) and plotted on the GIS topographic base maps (**Figure 5**). These point locations were adjusted as necessary to align them with the channel or valley floor shown on the map. The locations of the adjusted GIS points were compared to those on hard copy maps provided by the cooperator whenever possible. Seventeen of the 224 sites were omitted when they could not be located by the given coordinates and no topographic map was provided by the cooperator;

2. ***Basin Area Delineation*:** Drainage basins were delineated by identifying their stream divides on topographic maps. The stream divides were defined by lines drawn perpendicular to the elevation contours and through the highest elevations, as shown in **Figure 5b**. In 12 of the 207 sites either Pd or the drainage divide was not apparent on the topographic map and no basin divide could be drawn. Once the drainage divides were delineated, points Dc (the point where the stream trace intersects the divide) and Db (highest elevation point on basin divide) were located and added to the point data set;

3. ***GIS Measurements***: The delineated drainage basin areas were determined using the “ReturnArea” function in ArcView. Distances between points Dc, and Pd were determined by drawing a line perpendicular to contours and along the valley floor between these points. The lengths were calculated using the “ReturnLength” function in ArcView;

4. ***Union with other GIS Coverages*:** Elevation, precipitation, and ecoregion information was extracted for Pd, Pc, Ch, Dc, and Db using the DEM, PRISM precipitation, and USEPA Ecoregion GIS layers. These data were transferred to the database for statistical analysis.

Protocol Assessment

The pilot study protocol was evaluated to assess variability arising from the application of its procedures and definitions. To accomplish this task, we reviewed field training, assistance and replicate surveys as well as questionnaire responses from cooperators (**Appendices F and G**). Protocol compliance was also tested through statistical analysis of segment lengths, survey beginning and ending criteria, and success at recording requested data.

Qualitative methods to assess the replicability and overall adequacy of the protocol included reports from tribal training, field assistance, and quality control surveys, a formal cooperator questionaire (**Appendix G**), and information from review of data-entry materials. This qualitative analysis results in a list of recommendations.

Quantitative assessment of field data consistency and capture success was determined by means of statistical analysis. More specifically,

- “Consistency” estimates the degree to which the field parties followed protocol requirements for segment length and survey initiation and ending.
- “Capture success” estimates the degree to which field parties observed, measured, and recorded the required field data in **Tables 6** and **7**.

The capture and consistency measures were calculated by the ratio of number of sites meeting the protocol requirement to the number of sampled sites. Whenever the ratio exceeds 90 percent, the consistency/capture is judged to be high. A rate less than 90 percent may indicate that a change in protocol, variable definition, or training should be considered.

Data Analysis

This report emphasizes Pd because it is the hydrologic transition between perennial and seasonal water (Type Np/Ns Water break) as defined in FFR and WAC 222-16-030(3). Pc and Ch data are presented for reference purposes in some tables, figures, and appendices and are included in the text only as necessary.

Statistical routines in Excel, SAS, and SPSS were used to calculate summary statistics, correlation, analysis of variance (ANOVA), least squares regression, analysis of covariance, and Student’s t-test to assess the channel and basin area data. Summary statistics were calculated from the observed data and a log transformation was used to normalize skewed distributions for statistical analyses. Because this is a pilot study seeking potential differences, comparisons are considered significantly different at the 90% level. The survey data were grouped into study areas by ecoregion and default region strata:

- **Study Area**: A study area consists of randomly distributed surveys provided by one cooperator and located within one ecoregion. This distinction is necessary because some cooperators provided survey data from sites in more than one ecoregion (Longview Fibre Corporation - LVF, Colville – COL - and Spokane Tribes - SPO). Study areas were used to test for variation within ecoregions and FFR default regions
- **Ecoregions**: Washington is divided into eight level III ecoregions by the EPA (**Figure 1**). Level III ecoregions are based on the analysis of the patterns and the composition of the vegetation, wildlife, and physical phenomena (geology, topography, climate, soils, land use, and hydrology) that affect or reflect differences in ecosystem quality and integrity (Omernik 1987, 1995).
- **FFR default regions:** FFR divides the state into three default regions for which default basin areas are specified (**Figure 1**). Study areas occur in the 300-acre (Eastside) default basin region and the 52-acre (Westside) default basin area. No study area occurs exclusively in the 13-acre default region (Coastal). However, the HOH study area in Ecoregion 1 encompasses both the Westside and Coastal default regions (three study sites) and for the purposes of this study the HOH data are included in both the Westside and Coastal default regions.

Measure of Central Tendency

The measures of central tendency are the average and median of the data distribution and both are used in this study. In a skewed distribution, such as occurs in the pilot study, the median is the appropriate statistical measure of central tendency because it is less affected by extreme values (Haan, 1977). Skewed data are generally transformed such that the resulting distribution is approximately normal.

Since the pilot study data are approximately log normally distributed, a logarithmic transformation was applied before statistical computations (e.g. sample size, confidence intervals, and correlation testing) were performed. The log-averages, when transformed back into the original arithmetic values, correspond to medians (Evans et al., 1993). Thus, the results of these statistical analyses apply to the observed median values. Transformation also facilitates interpretation of customary descriptive statistical metrics, such as standard deviation, which lose their intuitive significance when applied to skewed data. Although the median is the most appropriate measure of central tendency in this study, the average is included in the text and tables. The uncertainty of which measure of central tendency the default basin areas represent requires that both measures be included.

Sample Size

The sample size required to estimate the log-transformed average of the observed basin areas in each FFR default region was based on the 90% confidence interval for the log-transformed average and several levels of precision. The approximate 90% confidence interval for the log-transformed average, which becomes the median when back-transformed, is estimated using a normal Z-statistic by:

$$\boldsymbol{Mean} \pm \frac{\boldsymbol{Standard\ Deviation}}{\sqrt{\boldsymbol{n}}} \bullet 1.65$$

This provides a method to estimate sample sizes needed to achieve desired precision levels defined by the relative size of the confidence interval by;

$$\boldsymbol{n} = \boldsymbol{CV}^2 \frac{1.65^2}{\boldsymbol{r}^2}$$

where ***r*** is the relative size of the confidence interval (i.e.

$$\left(\frac{\boldsymbol{Standard\ Deviation}}{\sqrt{\boldsymbol{n}}} \bullet 1.65\right) = \boldsymbol{r}\ \boldsymbol{*Mean}\}$$

and ***CV*** is the coefficient of variation of the population

$$(\frac{\boldsymbol{Standard\ Deviation}}{Mean} *100).$$

The sample-size equation has two inputs – the desired confidence interval of the transformed data (preliminary value of $\underline{+}$10%) and the coefficient of variation (estimated from the variability of available data). See **Appendix H** for further information on sample size.

Sample size was estimated from the pooled data for each FFR default regions because the sample data were distributed throughout the default regions. We assumed that the C.V. from the pooled data is most likely to approximate the maximum variance of the population under study, and therefore will produce a sample size sufficient to estimate the average of the true distributions. Because of this assumption, the estimated sample size should be considered as the minimum required in case the true variance was underestimated.

Alternative Field and Default Criteria

Alternate field and default criteria were sought by comparing the values of channel characteristics at the Np/Ns break to those at other segment breaks. A potential field criteria for the Np/Ns break was considered to be a physical variable that occurred more frequently at the Np/Ns break than at other flow-category segment break (i.e. a segment break occurring at a change in flow category rather than the 30-meter length limit) or a change in the magnitude of a channel characteristic (e.g. channel depth or substrate) at the Np/Ns break that was different from the change that occurred at other flow-category segment breaks.

Year of Normal Rainfall

We evaluated whether 2001 was "a year of normal rainfall" by analyzing annual and monthly precipitation during the field season and the preceding water year (October 2000 – September 2001) at NOAA long-term weather stations close to study areas (**Table 11**), which were available through the Western Regional Climate Center. Monthly totals with more than three daily values missing were eliminated (with the exception of March at Doty), as were water years with one or more missing months.

Annual and monthly precipitation values for the Water Year (WY) 2001 were compared to the quartiles of the long-term data. The following terms were applied to each quartile:

- First quartile (0-25th percentile): Unusually Dry
- Second quartile (25 – 50th percentile): Moderately Dry
- Third quartile (50 - 75th percentile): Moderately Wet
- Forth quartile (75 - 100th percentile): Unusually Wet

The range contained within the second and third quartiles are interpreted as being "normal". This definition places half of all monthly and annual precipitation totals within the normal range. The quartile approach is useful for evaluating seasonal trends within the annual totals.

Inference Capabilities

Because cooperators chose study areas for their convenience, the study areas are not randomly distributed within either ecoregions or the FFR default region strata. For this reason, statistical inferences based on pooled or combined data sets should be assessed using professional judgment.

Location of the channel head was not required by the protocol and thus was not captured in many surveys. Without its capture, the highest occurrence of perennial water may have been missed and the identified Pd in these surveys would thus be located downstream from the true Pd. This problem is believed to be concentrated in three study areas: TCG on the Westside and the SPO and COL in ecoregion 15 on the Eastside.

SECTION 3. RESULTS

Protocol Assessment

The pilot protocol (**Table 5** and **Appendix C**) was assessed for its adequacy and replicability and for the adequacy of the 200-meter survey beginning and ending criterion. The quantitative assessment is presented first and qualitative assessment second.

Quantitative Assessment

The protocol adequately defines the procedures and criteria for identifying segment breaks. The pooled segment lengths have a highly skewed distribution toward shorter lengths with an average and median length of 16 meters (52 feet) and 11 meters (36 feet) respectively (**Table 9**). The maximum segment length is 389 meters (1,275 ft) and only 133 of the 3,385 segments (4%) in the analysis exceeded 31 meters (102 feet) in length. Field notes indicate that segments exceeding the maximum length (30 meters) had steep gradients, waterfalls, or impenetrable vegetation that resulted in the field parties not being able to access the channel for measurement. The compliance rate of 96% indicates that overall consistency was high and no changes are required for segment definition.

Table 9: Segment Lengths: Summary of segment lengths reported by the 2001 field parties. Length should not exceed 30 meters.

Statistic	Segment Length (meters)	
	All	>31 meters
Sample Size	3,277	131
Average	16.7	61.9
Median	11.8	45.3
Minimum	1.0	31.0
Maximum	389.4	389.4
Standard Deviation	17.3	54.6
1st Quartile	7.0	34.0
3rd Quartile	28.0	61.2

The protocol did not adequately identify procedures and criteria for identifying the upstream extent of a survey. The protocol requires that the survey continue upstream 200 meters (656 feet) beyond the last perennial water (Pd) or to the channel head (Ch) whichever came first. Field parties were not required to record the presence of Ch, which was recorded in only 29 (14%) of the 213 complete surveys. In an additional 112 (53%) surveys, Ch was identified from descriptions in the field data sheets by the change in channel category to "no channel." The channel head was neither recorded nor identifiable from field data in 73 surveys (34%) for a compliance rate of 66%.

The field parties could not consistently obtain the channel characteristics required by the pilot protocol. The capture rates for the channel variables listed in **Tables 6** and **7** range from very high to low. **Table 10** compares the number of identified segments (3,513) with the number of segments including a record for the requested field parameter. A high (>90 % success) capture rate occurs for segment length and for flow and channel categories. Very low capture rates (<75 %) occurred for bankfull width and depth, gradient, and associated features. Dominant substrate was captured 88 % of the time. Gradient is difficult to assess because some survey parties measured upstream and downstream gradient from each segment junction (clinometer method), and some parties recorded gradient between segment junctions (laser range finder).

Table 10: Capture Rates. The percentage of field parties that recorded requested information at each segment break. The requested observations are listed in Tables 6 and 7.

Feature	Number Observed	Percent Captured by Field Parties
Segment Distance	3,611	100
Flow Category	3,565	99
Channel Category	3,559	99
Bankfull Width	2,723	75
Bankfull Depth	2,692	75
Upstream Gradient	2,255	62
Downstream Gradient	2,220	61
Segment Gradient	1,874	52
Dominant Substrate	3,183	88
Associated Feature #1	873	24
Associated Feature #2	57	2

Qualitative Assessment

A protocol specification for each cooperator was two replicate surveys by different field parties. The short duration of the 2001 field season placed the cooperators in the position of either including additional study sites or replicating surveys. Every cooperator chose the latter option. The independent contractor was not able to visit tribal cooperators to both validate protocol implementation and to conduct replicate surveys. Hence, the replicability of the protocol was not assessed.

The QA/QC report and responses to the questionaire (**Appendices F** and **G**) raised the following substantive issues about the adequacy of the pilot field protocol to fully capture and describe the Type N stream characteristics:

- Spatially intermittent flow categories should be combined, particularly the "Flowing Pocket Water" and "Standing Pocket Water" flow categories because they are difficult to distinguish
- Treatment of Piped Channels requires clarification.
- Bankfull width and depth are difficult to determine in the field because of indistinct channel edges.
- Gradients are oftentimes difficult to measure because vegetation obscures the channel and valley floor.
- Riparian vegetation should be substituted for upland vegetation in the site description.

Data collation and analysis indicated the field protocol/data dictionary should emphasize the search for piped channels. Piped channels are channels that run under the substrate or forest debris. Flow is typically heard and occasionally visible through small holes in the substrate. Piped channels were encountered in 52 study sites on the Westside. Important hydrologic transitions were located within these channels --Pd occurred within a piped channel at 18 (35%) of these sites and Ch occurred within piped-channels at 9 (17%) of these sites. Identification of piped channels was not required by the protocol but was available as a channel category when observed.

The FFR does not include piped channels as a category of typed waters. Appendix B in the FFR indicates that Type N channels must be connected to Type F or S channels by 'above ground channels' but it does not place similar constraints on the Np/Ns break (Pd) or channel head. If in some future FFR revision, piped channels are defined as macropores and not part of stream channel Pd and Ch would be placed at the at the last expression of the open channel and be interpreted as a channel-head spring.

Some cooperators encountered segments that were scoured to bedrock by recent debris flows and lacked both an alluvial/colluvial valley fill and channel. These segments were designated "poorly defined channels" because of the lack of a more appropriate category. The addition of the channel categories – "debris-flow scoured" and "debris flow deposits" -- would facilitate the identification of these segment types and provide information on the distribution of valleys affected by debris-flows. The variation in alluvial thickness in debris-flow dominated reaches probably influences the position of Pd within them. As alluvium/colluvium fills the hollow, Pd should move down stream because of the increased underflow.

Study Areas

Field data were collected in 15 study areas. A study area is composed of two or more sites surveyed by one cooperator within one Level III ecoregion. Study area locations are shown in **Figure 1**. All surveys were conducted between August 1 and October 11, 2001.

Average Annual Precipitation: The long-term (PRISM) average annual precipitation for a study area ranges from 375 mm (15 inches) on the Eastside to 3,125 mm (125 inches) on the Westside (see **Figure 11** for map).

Elevation: The median elevation of study areas range from 100 meters (~300 feet) in the Puget Lowlands (ecoregion 2) to 1,400 meters (~4,700 feet) in the Northern Cascades (ecoregion 77E) and Northern Rockies (ecoregion 15) with the higher median elevations on the Eastside.

Divide Relief: Divide relief is generally between 70 and 200 meters (~210 and ~600 feet) and is greatest (>200 meters) in the Northern Rockies (ecoregion 15)

Divide Gradient: Median divide gradient ranges from a low of 19% in ecoregion 2 (Puget Lowland) to 168% in ecoregion 1 (Coastal Range) with the steepest gradients in the Coastal Ranges and Northern Cascades (<158%).

Year of Normal Rainfall

Precipitation data from the closest long-term meteorological station to each study area are presented in **Table 11**. Key observations are:

- The 2001 water year was "unusually dry" for all stations;
- The water year shortfall resulted from four consecutive "unusually dry" winter months (Nov-Feb);

- A return to moderately to unusually wet conditions occurred in March or April and continued through August or September;
- On the Eastside the moderately to unusually wet months alternate with moderately to unusually dry months;
- July was moderately dry at most stations.

Detailed interpretation of **Table 11** is deferred to the Discussion section.

Table 11: Year of Normal Precipitation: Precipitation data for the water year 2001 summarized by the meteorological station closest to each study area. The monthly and annual data are compared to the long-term record for the station and assigned to the appropriate quartile of the precipitation distribution.

Precipitation Station	2000			2001									Water Year
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Total
Coastal													
Forks (HOH)	*9.8*	***6.3***	***10.1***	*13.6*	***3.8***	*9.6*	9.4	6.4	3.6	*1.2*	**7.6**	4.7	***86.1***
Westside													
Bremerton (SUQ)	4.7	***4.0***	*6.2*	***4.4***	***2.3***	**4.9**	*2.9*	*2.8*	**3.0**	**1.7**	**3.7**	*0.6*	***41.9***
Doty (DFW)	*3.8*	***3.5***	***2.2***	***3.4***	***2.4***	***3.7****	3.9	2.8	2.7	*0.5*	**1.5**	*0.9*	***31.4***
Skamania (LVF)	7.0	***5.6***	***6.0***	***4.7***	***3.4***	*8.1*	7.1	4.4	**5.6**	*1.1*	2.0	***1.5***	***56.5***
Longmire (TCG)	*7.5*	***6.0***	***4.9***	***5.3***	***4.2***	*6.7*	6.1	4.9	**6.3**	*1.4*	1.4	*1.2*	***56.1***
Sedro Wly[1] (SSC)	4.3	***2.4***	***3.6***	5.0	***1.8***	4.3	**4.3**	*2.6*	5.0	*1.0*	2.0	*1.6*	***37.9***
Eastside													
Leavenworth (LVF)	*1.2*	***1.5***	*2.3*	***1.6***	***1.5***	2.1	***0.6***	***0.8***	1.2	***0.0***	***0.6***	0.2	***13.6***
Republic (COL)	*0.9*	***0.9***	*1.1*	***0.6***	***0.4***	1.7	***0.6***	***0.7***	1.8	*0.9*	***0.2***	0.9	***10.7***
Stamp. Pass[2] (YAK)	*4.0*	***5.8***	***5.6***	***5.6***	***4.0***	7.7	6.2	*4.2*	4.4	*1.4*	1.4	***1.2***	***51.5***
Winthrop (COL)	1.0	*1.2*	*1.2*	***0.5***	***0.7***	1.0	*0.4*	***0.1***	*0.8*	*0.6*	*0.3*	0.5	***8.3***

Category Codes:	***Bold Italics*** = Unusually Dry	< 25th percentile of long term record
	Italics = Moderately Dry	25th to 50th percentile of long term record
	Regular = Moderately Wet:	50th to 75th percentile of long term record
	Bold Regular = Unusually Wet	> 75th percentile of long term record

1 Sedro Woolley
2 Stampede Pass
* Doty record: seven days missing for March 2001

Basin Area Variability

A total of 109 basin areas (Ch, Pd, and Pc) were determined for Eastside sites and 385 (Ch, Pd, and Pc) were obtained for Westside sites. Only the summary statistics for basin areas above Pd are included in **Table 12**. The averages of the observed Pd basin areas for the three FFR default regions (Coastal, Westside, and Eastside, respectively) are 8, 22, and 118 acres and the medians are 2, 6, and 36 acres.

Table 12: Basin Areas above Pd. Descriptive statistics of basin areas above Pd (Np/Ns break) by FFR default region.

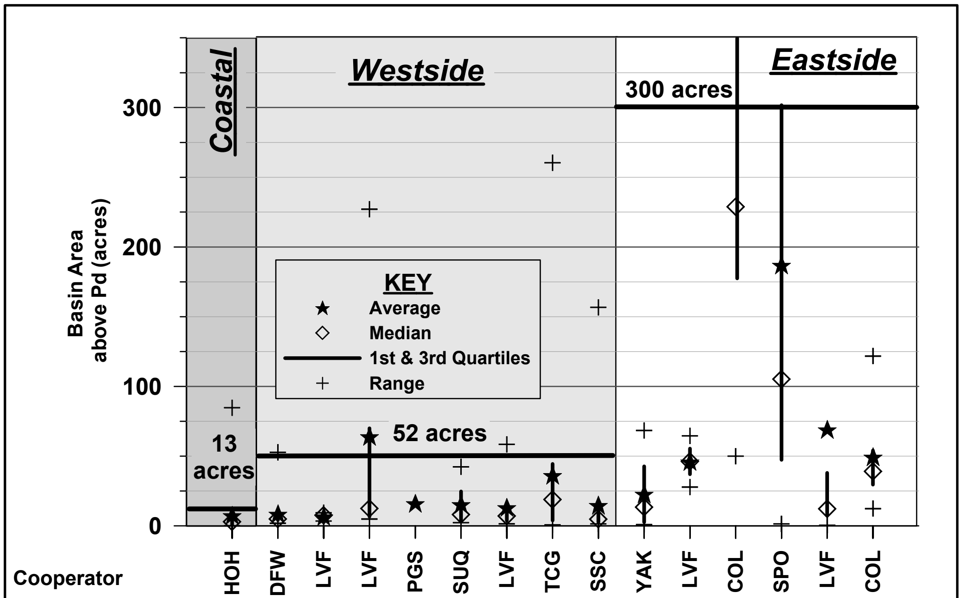
Statistics	Eastside (300 acres)	**Westside** (52 acres)	**Coastal** (13 acres)
Sample Size	43	152	18
Average (acres)	118	22	8
Median (acres)	36	6	2
Standard Deviation (acres)	242	42	20
Minimum (acres)	0.4	0.1	0
Maximum (acres)	1,224	260	85
1^{st} Quartile (acres)	9	3	1
3^{rd} Quartile (acres)	68	22	5
Coefficient of Variation	206	191	249

The observed basin areas differ between and within FFR default regions and between study areas within default regions (**Figure 8).** The average and median are shown as points (star and diamond, respectively), the central 50 percent of the data as defined by the first and third quartiles is a solid line, and crosses bracket the range. **Figure 8** shows the following:

- The FFR default basin area is larger than the 75% of the measured basin areas in all (13) but two study areas (LVF – 2, COL – 15).
- Within each FFR default region, the central 50% of the data distributions for each study area overlaps the others, with the exception of COL and SPO in ecoregion 15.
- The study areas in ecoregions 4 and 77, which straddle the Cascade crest, have similar distribution.

These observations were tested by ANOVA with following results:

- Basin areas between FFR default regions are significantly different at p = 0.01.



Cooperator	HOH	DFW	LVF	LVF	PGS	SUQ	LVF	TCG	SSC	YAK	LVF	COL	SPO	LVF	COL
Number of Sites	22	34	3	4	1	6	15	61	25	13	2	6	6	13	5
Ecoregion	1	1	1	2	2	2	4	4	77W	4	9	15	15	77E	77E
Average Area (acres)	8	9	7	64	16	15	13	36	15	23	46	494	187	69	50
Median Area (acres)	3	5	8	12		8	7	19	5	13	46	229	105	12	39

Figure 8: Basin areas above Pd by study area. Study areas are identified by cooperator (Table 3) and ecoregion (Figure 1). The heavy horizontal line in each FFR default region defines the default basin area for that region. The average and median values for each study do not coincide because of the skewed, lognormal distribution of the basin areas. Surveys in COL-15, SPO-15, and TCG did not reach the channel head and the basin areas may be biased toward larger areas in these study areas. The COL-15 distribution is truncated

- Study areas within each FFR default region are significantly different from each other at $p = 0.004$ and 0.04 respectively.
- The study areas in ecoregion 77 (SSC, COL and LVF) are significantly different ($p = 0.02$) from each other.
- The study areas in ecoregion 4 (LVF, TCG, and YAK) are not significantly different ($p = 0.4$)

Sample Size

The sample size required to estimate the observed median basin areas in **Table 12** at the 90% confidence interval changes with the precision selected. With a 10% precision, it is estimated as 84 and 99 for the Eastside, and Westside, default regions respectively (the Hoh study area is excluded from Coastal FFR, for the sample size analysis). If the precision is decreased to 15%, the sample sizes

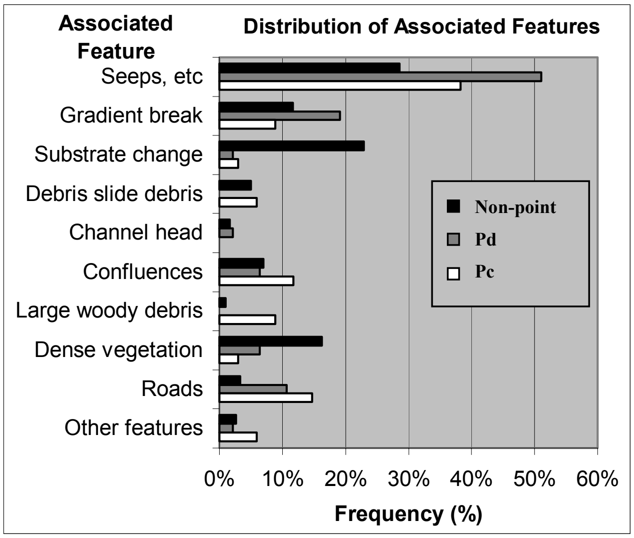


Figure 9: Histogram of associated points at flow-generated segment breaks. The histogram compares the frequency at which associated features occur at segment breaks defined by a change in flow category.

become 38, 45, and 291 for the three regions, or about half of the sizes estimated with 10% precision. Sample size requirements are more fully developed in the Discussion section.

Field Indicators of the Np/Ns Break

Changes in flow category accounted for 2,361 segment breaks. However only 117 (5%) of these were actual Pd locations and only 57 (44%) of these had associated features recorded. In **Figure 9** the frequency of associated features at Pd segment breaks are compared with their frequency at other flow-change segment breaks. The most frequently noted features were “springs”, “seeps”, and “wetlands”, which occurred at over 70 percent of the Pd and Pp breaks, and are the only FFR criteria for identifying the Np/Ns break. Roads are the only other associated features that are more frequent at Pd and Pp than at other flow-category breaks. Because these associated features are commonly found elsewhere they show little potential to conclusively identify Pd outside the dry season. Likewise, none of the other associated features appear to be definitive field indicators of the Np/Ns break.

Changes in channel variables at Pd were determined by comparing the segment upstream of Pd to the segment downstream. The variables included in this analysis were:

a) Substrate
b) Bankfull width
c) Bankfull depth
d) Segment gradient

The upstream/downstream values of these variables were not significantly different at $\alpha = 0.10$ and therefore are not suitable field predictors of Pd.

Table 13: Basin area correlation with site variables to determine which site variables covary with basin area. Correlations expressed as r^2 between Pd basin area and site variables. All r^2 are significant at $\alpha = 0.1$ but only those correlations with $r^2 > 0.50$ are considered meaningful.

Variable	Log Pd Basin area	Sample Size
Log Ppt	-0.25	162
Db Elevation	0.13	124
Dc Elevation	0.12	150
Pd Elevation	0.08	157
Basin Relief	0.27	120
Divide Relief	0.19	146
Log Dc - Pd	0.77	125
Log Divide Gradient	-0.16	105

Other Indicators of the Np/Ns Break

Because the search for field indicators of Pd did not provide channel-scale predictors, possible site-scale candidates were sought through the correlation of observed basin areas with the site-scale topographic parameters in **Figure 6**. In this analysis, the data were pooled to provide data sets that ranged between 80 and 162 pairs. Distance from divide is the only meaningful correlation at $r^2 = 0.75$ (**Table 13**) and its relationship to basin area was explored.

The summary of divide distances to Pd by FFR default region (**Table 14)** indicates the average divide distances are short being 245 meters (804 feet) in the Coastal region, 431 meters (1,379 feet) in the Westside, and 780 meters (2,558 feet) in the Eastside. Corresponding median distances are 538 meters (1,765 feet), 333 meters (1,065 feet) and 212 meters (695 feet) in the Eastside, Westside and Coastal regions, respectively.

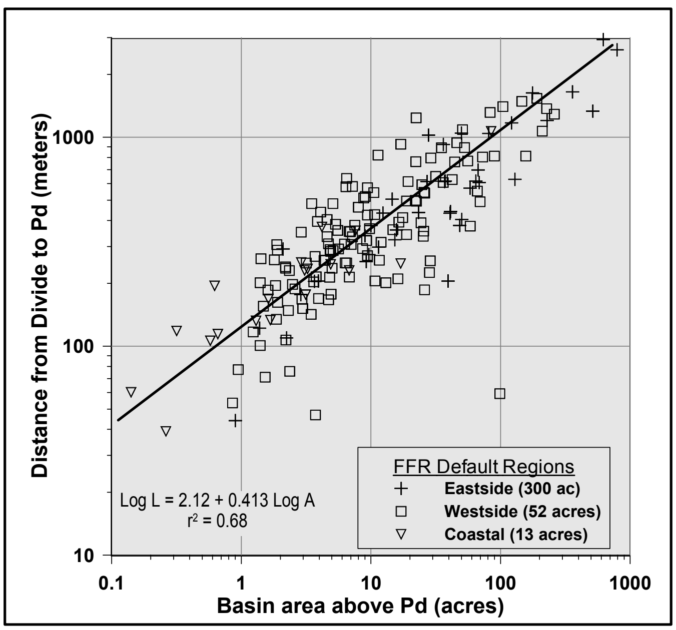


Figure 10: Distance from divide vs. Basin area. Scatter diagram showing the relationship between distance from divide to Pd and basin area above Pd. Regression equation for all data is highly significant.

Their C.V.s are less than 90 %, which makes distance from divide significantly less variable than observed basin areas (C.V.> 182%).

Distance from divide is strongly related to basin area (**Figure 10).** Regressions of distance from divide to Pd upon basin area above Pd are significant (**Appendix** I) for (1) sites within a study area, (2) study areas within a FFR default region, and 93) default regions within the state. Analyses of covariance of the interaction of study areas indicate no significant differences ($p>0.2$). The state regression in **Figure 10** thus expresses the relationship between basin area and distance downstream from divide at all study areas across all ecoregions.

Table 14: Distance from divide to Pd. Descriptive statistics for distance from divide (Dc) to Pd by FFR default regions.

Statistic	Eastside (300 acres)	Westside (52 acres)	Coastal (13 acres)
Sample Size	38	117	18
Average (m)	780	431	245
Median (m)	538	333	212
Standard Deviation (m)	730	319	222
Minimum (m)	44	39	39
Maximum (m)	2,933	1,534	1,065
1^{st} Quartile (m)	327	214	132
3^{rd} Quartile (m)	1,038	544	248
Coefficient of Variation	94	74	90

Alternative Stratification Schemes for FFR Defaults

We tested three alternative hypotheses for establishing FFR default regions based on a single physical attribute – average annual precipitation, elevation, and relief. Because basin areas were not significantly different when grouped into three classes based on elevation or relief, these two attributes were eliminated as potential criteria. Precipitation classes have significantly different basin areas and slightly lower C.V.s.

The distribution of the average annual precipitation in Washington is shown in **Figure 11**, which is based upon PRISM model data. These data were used to determine the precipitation distribution at Pd (**Figure 12)**, which was divided into three classes for a preliminary analysis of basin areas:

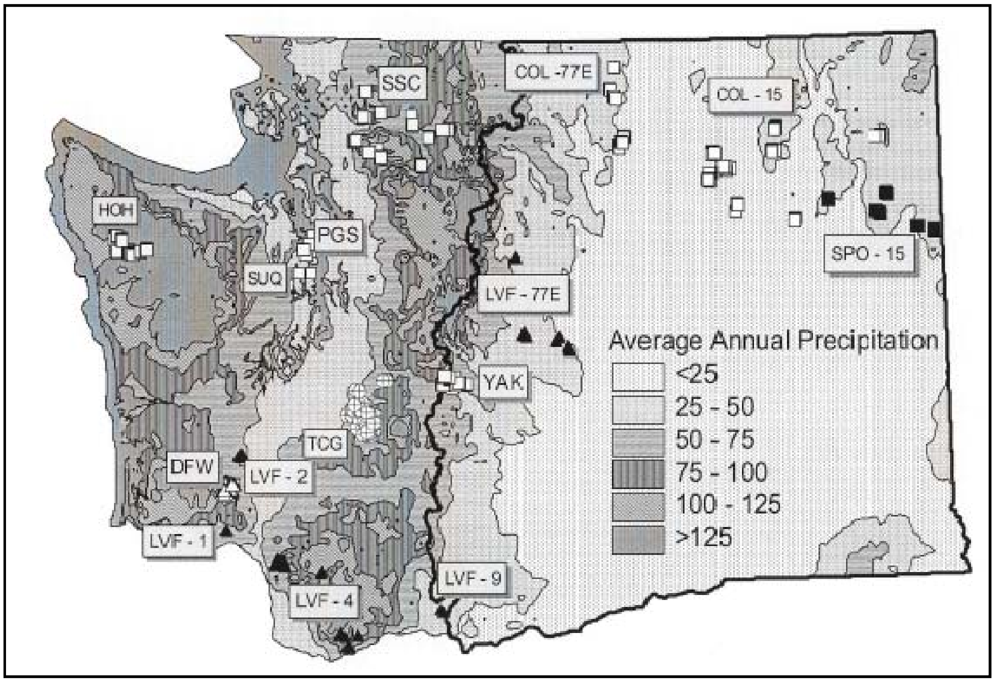


Figure 11: Average Annual Precipitation Classes. The distribution of study areas relative to average annual precipitation classes developed from PRISM data. A heavy north-south line shows the Cascade crest. It divides the sate into Eastside and Westside FFR default regions. Note that sites occur in all precipitation classes and that some classes appear on both sides of the Cascade crest.

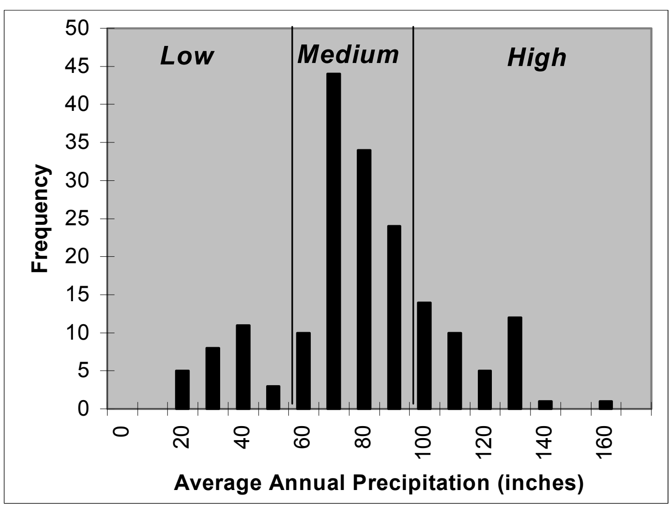


Figure 12: Histogram of Average Annual Precipitation. The frequency of precipitation values occurring at Pd in 218 study sites in the state. The precipitation classes used in the analysis are labeled Low through High.

- Low (<30 to 60 inches, <750 to1,500 mm)
- Medium (60 to 100 inches, 1,500 – 2,500 mm)
- High (100 to 160 inches, 2,500 to 4,000 mm)

Table 15 presents the median and average observed basin areas for the three precipitation classes. With increasing average annual precipitation, the average basin areas decrease from 122 acres to 10 acres, and median basin areas decrease from 27 acres to 3 acres. ANOVA indicates that the basin areas in the different precipitation classes are significantly different. The C.V.s for the three-precipitation classes ranges from 163% to 197% and are slightly smaller than the C.V.s for default regions (182% to 249%).

Table 15: Basin area above Pd by precipitation class. Class boundaries selected to divide precipitation range into approximately equal cells. Total number of sites in "Included sites by FFR default region" exceeds number used to develop statistics because not all included sites had basin area data.

Statistic	Average Annual Precipitation (inches)		
	<30 to 60 inches	60 – 100 inches	100 to 160 inches
Sample Size	45	122	28
Average (acres)	122	22	10
Median (acres)	28	7	3
Standard Deviation (acres)	239	36	19
Minimum (acres)	0.4	0.7	0.1
Maximum (acres)	1,224	210	85
1st Quartile (acres)	9	4	2
3rd Quartile (acres)	81	25	7
Coefficient of Variation	197	163	190
Included Sites by FFR Default Region			
Eastside	33	12	1
Westside	13	124	10
Coastal	0	0	21

SECTION 4. DISCUSSION

Protocol

The analysis of the pilot study indicates that the field protocol is generally adequate but requires some modifications. The parameters included in the pilot study proved to be appropriate to answering many of the initial questions. Some additions and deletions are recommended to either streamline data collection or to provide the additional data required for new hypotheses recommended for testing. New parameters recommended for inclusion in the protocol are channel head, valley width, debris-flow scour, and debris-flow sediments. Recommended for deletion are bankfull channel width and depth.

The channel head (Point Ch) is an important hydrologic feature as it marks the beginning of channelized stream flow and usually can be identified during most seasons. Inclusion of Ch was not required by the pilot survey because the emphasis was on point Pd. Numerous surveys that did not reach the channel head may have missed isolated wet channels segments upstream of the previously identified Pd and thereby increased the average basin areas and distances from divide (Dc – Pd) and from the channel head (Ch – Pd). Because the channel head appears to vary in shape and degree of definition (Dietrich and Dunne, 1993; Roth and La Barbera, 1997)), there should also be a certainty assessment (e.g. “definite”, “certain within a few channel widths”, “gradational over X distance”, “uncertain”).

The importance of valley width is uncertain. It may be an important control on the expression of surface flow (Kasahara and others, 2003; Storey and others, 2003) because it along with sediment depth and permeability controls the quantity of subsurface flow through the alluvial fill within the valley. Zellweger and others (1989) found that subsurface flow through alluvium could about 25 percent of the surface flow and that aggradation of coarse sediment can increase the proportion of subsurface flow. Its inclusion in the study would allow the more complete analysis of the controls on Pd and the observed variability in basin area and distance downstream.

The addition of two channel categories would facilitate the assessment of debris-flow impacts. The additional channel categories are:

- "Debris-flow scoured" valleys containing little to no sediment on the valley floor because of recent debris-flow activity. The lack of sediment inhibits the development of a channel and perennial flow may occur further up stream because of the low storage within the valley. As colluvium and alluvium accumulate on the valley floor, perennial flow may begin farther down stream.
- "Debris-flow sediments" a valley floor containing debris-flow sediments. When the sediments are of sufficient thickness or high permeability surface water may disappear as underflow becomes dominant.

These channel categories will identify debris-flow prone valleys and allow the assessment of their uniqueness and potential impact on the location of the Np/Ns break. It is anticipated that debris-flows may affect a large proportion of the valleys in mountainous areas (Dunne, 1998; Montgomery, 1999; Whiting and Bradley, 1993).

The field parties recommended that bankfull channel width and depth be removed. Bankfull channel width and depth are difficult to measure because in many cases the channel edge is often indistinct in small streams. Because of this problem, the recorded channel widths and depths maybe inaccurate.

Several changes to the protocol would refine the data collected or streamline data collection. Field parties indicated that substrate was difficult to assess for a segment based on flow category. Allowing segment breaks at substrate changes could reduce the substrate identification problem and allow a fuller assessment of the association between substrate and Pd. The field parties also emphasized the large amount of time consumed by recording segment information at segment lengths of 30 meters (98 feet) or less and encouraged the increase in segment length to 100 meters (328 feet). This increase appears reasonable if both changes in flow and substrate categories are criteria for forced segment breaks.

Future surveys should emphasize the site and channel conditions occurring at Pd. Although the field protocol includes lists of possible indicators, the lists may not be sufficiently inclusive and an open-ended description may identify additional indicators.

Often the field coordinates for points do not plot on a recognizable drainage way on the USGS 7.5 minute topographic maps (Meyer and Wallace, 2001). The field party has the best understanding of the relationship of the survey to the topography and topographic map. Therefore they are in the best position to make any changes, such as moving a point to fit map, or plotting the drainage that does not appear on the map.

Year of Normal Rainfall

Different conclusions are possible from the 2001 precipitation data depending on the interval analyzed – the 2001 water year or the summer of 2001. The water year analysis indicated that WY 2001 had an unusually dry winter followed by a moderately wet summer that produced an unusually dry water year (**Table 11**). Based on the quartile definitions adopted here, 2001 was not "a year of normal rainfall." Rather 2001 was a year of less than normal rainfall that could be expected to produce longer dry reaches within headwater streams and move Pd downstream. Based on this annual assessment, we could anticipate Pd basin areas to be larger than normal and the length of the seasonal reach to be longer than normal. However, the moderately wet summer months may compensate for the winter drought by providing sporadic recharge to the subsurface reservoir that maintains perennial flow.

Summer conditions differed between the Eastside and Westside that could lead to different summer flow regimes. The monthly precipitation on the cooler Westside was typically two to three times larger than that on the hotter Eastside (**Table 11**). It is likely that more of the summer precipitation was lost to evapotranspiration on the Eastside than on the Westside. Consequently, little to no recharge to the soil reservoir would occur on the Eastside and some recharge to the reservoir could occur on the Westside. During the summer of 2001 it is likely that the Eastside had unusually dry flow conditions while the Westside had normal flow conditions. We judge that the Eastside basin areas and distances downstream are larger than those occurring during a year of normal rainfall and Westside basin areas and distances downstream are probably representative of a year of normal rainfall.

Basin Areas

The observed basin areas above Pd are less than the FFR default basin areas. As shown in **Figure 8**, the FFR default basin areas are larger than the 75th percentile of the basin area distribution in most study areas. When the data are pooled by FFR default area, the average observed basin area in each default region (Coast, Westside, and Eastside, respectively) are 8 acres, 22 acres and 118 acres, which is only 61%, 42% and 39 % of the FFR default basin area. Likewise, the median observed basin areas are 2 acres, 6 acres, and 36 acres, which are only 15%, 13 %, and 11.5% of the default basin areas (**Table 12**). The observed basin areas in this study do not differ from those reported by other studies. Basin area studies conducted by CMER participants prior to 2001 (**Appendix B, Table 2**) report average basin areas ranging from 11 to 138 acres and median basin areas ranging from 10 to 40 acres. These studies used different protocols to collect the data and different definitions for point "Pd" to produce results similar to those of the pilot study. This similarity indicates that

1. Differences in the definition of the Np/Ns break (point Pd) do not produce large changes in basin areas, and
2. Every available study indicates that a smaller basin area is required to maintain perennial flow in headwater stream than envisioned by the default basin areas in the FFR

The results of a study of perennial flow in Puget Lowland streams indicate larger drainage basin areas (Konrad, 2001). The study included 59 basins throughout Puget Lowland (ecoregion 2) that were surveyed in August 1998 and 1999. Streams with observed surface flow were designated perennial and those without flow were designated ephemeral (seasonal). It found that there was a 50% probability for perennial flow where the drainage basin was less than 1.2 km^2 (296 acres).

Basin Area Variability

The observed basin areas differed significantly between ecoregions within FFR default regions (**Figure 8**). The observed geographic variation in basin areas may result in part from differences in precipitation within FFR default regions as shown by the precipitation analysis (**Table 15**). Castro and Jackson (2001) reached a similar conclusion in their analysis of bankfull discharges in the Pacific Northwest. They determined that although ecoregions included the statistically most significant spatial factors controlling bankfull discharges, climate regionalization was also significantly related to bankfull discharge. The authors attributed this duality to the climate-adapted vegetation associations in each ecoregion that controlled runoff conditions.

Physiographic variables do not appear to control perennial flow. As shown in Table 13, Pd basin area is not related to elevation or relief. The Puget Lowland study also found that perennial flow was related only to basin area and not to four other physiographic variables or degree of urban development (Konrad, 2001). They compared perennial flow to basin area, valley slope, valley relief, basin shape, and surficial geology. Perennial flow was related only to basin area and the contact between outwash and till. The study did not determine the changes in the extent of perennial flow that may have occurred during the initial clearing of the forests.

Precipitation Classes Defining Alternate Default Regions

Precipitation may be a more appropriate criterion for identifying FFR default regions. The precipitation classes in **Table 15**, which includes data from all FFR default regions, indicate the inherent heterogeneity of FFR geographically-based default regions. For instance, the less than 60-inch precipitation class includes 33 sites from the Eastside and 13 sites from the Westside. The precipitation class boundaries used in this analyses may not be the most appropriate, and if precipitation is used as the basis for default regions, further study to determine the most appropriate boundaries are recommended.

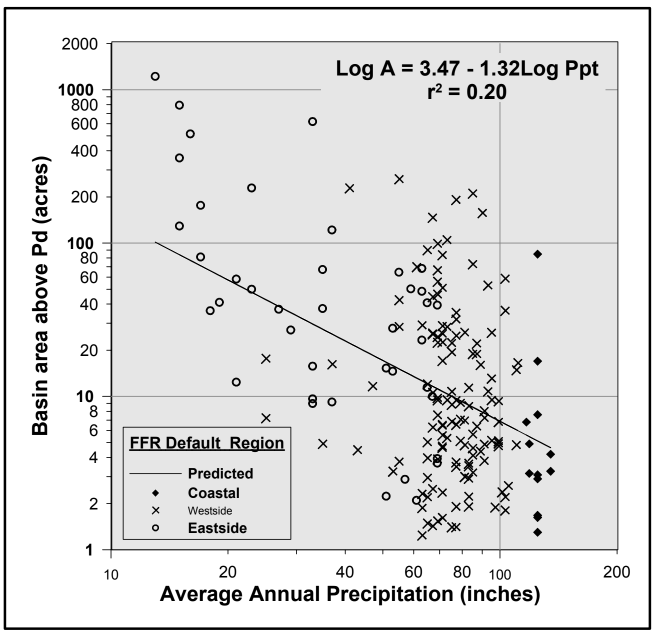


Figure 13: Scatter diagram of basin area above Pd to average annual precipitation at Pd. Sites are separated by FFR default region. The regression is the data pooled by state and is significant at $\alpha = 0.1$. The scatter about the regression is symmetrical for Westside and Coastal FFR region but biased toward larger basin areas for Eastside sites where the channel head was not captured.

Average annual precipitation is an appropriate default criterion because it is the dominant statewide control on basin area variability. The regression of basin area above Pd against average annual precipitation is shown in **Figure 13**. It demonstrates that basin area varies inversely with average annual precipitation. ANOVA indicates it is highly significant ($\alpha < 0.001$) although the fit is poor with an

$r^2 = 0.20$. The degree to which precipitation explains the variability in basin size, as estimated by (r^2) is low, which probably indicates the importance of other physical factors, such as geology or soil texture and thickness as controls on basin size.

Alternative Indicators

The Np/Ns break (Pd) is presently identified in the field by the occurrence of non-migrating seeps and springs. The phase 1 search for alternative field indicators was not successful. The lack of clearly defined changes at Pd indicates that a consistent and unique change was not present at Pd, and/or the 2001 protocol was not capable of detecting such a change that was indeed present. Although alternate field indicators could not be identified, a map-based alternative indicator was identified that is also a potential alternative to basin areas as a default criterion.

Distance from divide to Pd is an attractive alternative indicator and default criterion because, as shown in **Figure 10**, it is strongly related to basin area (Montgomery and Dietrich, 1992) and has a lower coefficient of variation (74% to 94%) than default basin areas (182% to 249%). Distance from the divide has the advantage of being more readily measured on maps – it is a line from the channel to the divide measured at perpendicular to the contours that is easier to identify and draw than a stream divide. For this reason distance from divide could be the basis for computer-generated default maps within the GIS environment. Distance from the divide may be difficult to measure in the field to locate Pd and does not substitute for a simple field indicator. However, length of the seasonal Type Ns reach may serve this purpose.

The seasonal channel begins at the channel head, which often can be identified in the field during snow-free conditions by a forester with appropriate training using clearly defined criteria. Once the channel head is identified, the location of Pd in the channel can be estimated from the length of the seasonal reach (Ch – Pd). The summary statistics for the seasonal reach by FFR default region are presented in **Table 16** with channel seeps and springs included (i.e. sites with no seasonal reach, which comprise 17 to 34 % of the sample) and with them excluded. The average length of the seasonal reach is similar for the Eastside and Westside regions – 21 to 24 meters (67 to 79 feet) with springs/seeps included and around 29 to 35 meters (93 to 112 feet) with them excluded. It is lower in the Coastal region with an average length of 4 meters (13 feet) with springs/seeps and 5 meters (16 feet) without them.

Table 16: Length of seasonal reach (Ch – Pd). Descriptive statistics for the length of the seasonal reach (meters) with reaches beginning at channel head (Ch) springs and seeps included (left) and excluded (right) from the sample.

Statistic	Channel Head Springs and Seeps Included			No Channel Head Springs and Seeps		
	Eastside (300 acres)	Westside (52 acres)	Coastal (13 acres)	Eastside (300 acres)	Westside (52 acres)	Coastal (13 acres)
Sample Size	23	126	18	16	92	15
Average	24	21	4	35	29	5
Median	6	10	2	10	17	2
Standard Deviation	45	33	6	51	36	6
Minimum	0	0	0	1	1	1
Maximum	180	225	22	180	225	22
1st Quartile	0	0	1	5	7	1
3rd Quartile	22	27	6	37	37	8
Coefficient of Variation	187	353	136	147	210	118
Channel head springs or seeps	7 (30%)	34 (27%)	3 (17%)	0	0	0

The presence of channel head springs/seeps in the sample affects the C.V. When channel head springs and seeps are included the C.V.s are between 136 % and 353% and generally exceed those of default basin areas (182% to 249%). When channel head springs/seeps are excluded, the C.V.s decrease to between 118 % and 210 % and are less than those for default basin areas.

Another alternative indicator of the location of Pd is the channel head. As shown in **Table 16**, the average length of the seasonal reach (Ch – Pd) is less than 35 meters (115 feet) and the corresponding median length less than 17 meters (54 feet). In place of other indicators, placement of the Np/Ns break (Pd) at the channel head would result in a median error of less than 10 meters (30 feet) in the Eastside, 21 meters (63 feet) in the westside, and 2 meters (6 feet) in the Coastal default region. This error is less than that introduced by the application of the present FFR default basin areas.

Table 17: Distance from divide (Dc) to Pd by precipitation class. Class boundaries selected to divide precipitation range into approximately equal cells. Total number of sites in "Included sites by FFR default region" exceeds number used to develop statistics because not all included sites had identified channel heads.

Statistic	Average Annual Precipitation (inches)		
	<30 to 60 inches	60 – 100 inches	100 to 160 inches
Sample Size	41	120	30
Average (m)	737	429	251
Median (m)	581	339	230
Standard Deviation (m)	634	305	195
Minimum (m)	47	44	39
Maximum (m)	2,933	1,534	1,065
1st Quartile (m)	284	215	132
3rd Quartile (m)	1,043	543	257
Coefficient of Variation	85	71	78
Included Sites by FFR Default Region			
Eastside	33	12	1
Westside	13	124	10
Coastal	0	0	21

Average annual precipitation classes also separate distance from divide to Pd into discrete classes with a low variance (**Table 17**). The precipitation classes indicate that distance from divide to Pd decreases from and average of 737 meters (2,417 feet) in drier areas to 251 meters (823 feet) in wetter areas and the median distances decrease from 581 meters (1,906 feet) in drier areas to 230 meters (754 feet) in wetter areas (the Eastside statistics are biased by the inclusion of sites wherein the channel head was not captured by the survey).

Sample Size And Design

The skewed distributions encountered in the pilot study skews the confidence interval about the average in the arithmetic data. The confidence intervals are symmetrical in the log-transformed data used to estimate the required sample size, but when back transformed, the confidence interval becomes skewed with a long tail toward larger values (**Appendix H, Figure 1**).

The sample design for the phase 2 statewide study should include:

1. Sample size,
2. Sample distribution, and

3. Stratification.

In order to assure a representative estimate of Pds across the selected strata (e.g. FFR default region or precipitation class), the sites should be selected with equal probability from the FFR lands within each stratum. Moreover, the estimated sample sizes should be considered minimum values so that statistical power will be adequate if actual variance was underestimated.

The estimated sample size depends on the stratification criterion. In **Table 18** sample sizes are listed for two stratification criteria – FFR default regions and precipitation classes -- and for two possible default criteria – basin area above Pd and Distance from divide to Pd. The estimated sample sizes are similar for both FFR default regions and precipitation classes because coefficients of variation for basin areas and for distance from divide do not change significantly. The large difference in sample sizes between potential default criteria -- basin areas and distance from divide -- results from the low CV and large median for the observed distance from divide.

Table 18: Estimated sample sizes. Sample size required to estimate the observed average basin area with a 10 percent confidence interval of different precisions. Average and CV (coefficient of variation) are estimated from the lognormal transformation of the observed data. Precision is the size of the 90% confidence interval as a percentage of the average. Dashes in the precision columns indicate estimated sample sizes less than one.

Default Variable	Cell	Stratum Average*	CV*	Sample size for a Precision of 5%	10%	15%	20%	25%
Basin Areas	FFR Default Region							
	Eastside	27	56	329	84	38	22	15
	Westside	6	70	532	134	61	35	23
	Precipitation Class							
	<60”	29	54	329	84	38	22	15
	60” – 100”	9	59	391	99	45	26	18
	100 - 150”	3	137	1,974	532	238	134	87
Distance from Divide to Pd	FFR Default Region							
	Eastside	540	14	26	8	--	--	--
	Westside	431	12	26	8	--	--	--
						--	--	--
	Precipitation Class							
	<60”	525	14	26	8	--	--	--
	60” – 100”	341	12	13	9	--	--	--
	100 – 150”	201	13	26	8	--	--	--

SECTION 4. POTENTIAL STUDIES

In addition to the proposed statewide Np demarcation study outlined in the previous section, the pilot study raised several related technical questions that could be addressed by either future studies or the proposed statewide study. These questions with an explanation follow.

1. ***Does the first appearance of perennial water in the channel (point Pd) change position relative to the channel head (point Ch) during the summer dry season?***

This question asks if low flow observations collected during one part of the summer dry season is representative of low flow conditions during other parts of the summer dry season. The limited intra-annual variation data collected in this study were not analyzed. Other studies (Mark Hunter and others, 2003) indicate no consistent pattern in the behavior of Pd during the summer. At some sites, the position of Pd was stable throughout the summer dry season, whereas, at other sites, downstream migration of Pd began at different times in August.

The issue of seasonal instability would be addressed by repeated surveys of representative streams beginning with wet conditions during the spring runoff and continuing through the entire summer dry season until wetter conditions return following the winter rains.

2. ***Does categorizing default criteria by annual precipitation classes predict point Pd with less variability than do the existing 13, 52, and 300-acre default area?***

Areas with similar amounts of annual precipitation occur both east and west of the Cascade crest. The analyses in the pilot study indicated that precipitation contributes to the observed variability in basin areas but the observed variability using precipitation classes was almost as large as that using FFR default regions. A study is recommended to determine the source and validity of this variability. A study with a sampling design that controlled for precipitation classes has would have two advantages:

1. It could reduce the observed variability, and
2. It would be based on a single physical attribute, one that has been shown to be a regional control of variability in basin areas and distances from divide.

The precipitation issue is complicated by our incomplete understanding of its control on perennial flow, i.e. is the annual or seasonal precipitation the primary control on Pd? FFR refers to a "year of normal rainfall" but alternative measures of precipitation (e.g. summer averages, difference between spring & summer, etc) may offer more effective predictors as these measures may be more hydrologically significant to perennial expression.

3. *Is the distance between the channel head (point Ch) or divide and the first downstream appearance of perennial water (Pd) a better predictor of this point than default basin area?*

The FFR requires the identification of simple, non-technical field indicator of the Np/Ns break, here identified as Pd. In most areas during snow-free conditions, the channel head can be identified by trained technicians and a default distance measured downstream from it. Moreover, the divide can be recognized on most topographic maps and the distance from the divide to channel marked off. The consistency of these distances can be evaluated by determining the location of both the channel head and Pd during future surveys.

Several cooperators noted that low relief valleys were sometimes incorrectly mapped or did not appear on the topographic map. The inaccuracy of the topographic base maps may limit the use of the divide as a default criterion (if so, the same limitation exists for default basin areas).

4. *Do headwater streams susceptible to debris flows have different physical characteristics that affect the location of Pd and Pc?*

The pilot survey did not request information on debris-flow activity except to note where debris-flow sediments caused a change in flow category. At least one cooperator (HOH) noted that channels were poorly defined in debris-flow scoured valleys because of the lack of sediment (Dunne, 1998). The location and behavior of Pd and Pc should be different in these valleys (Gomi, 2002).

Several classification of headwater streams that appear in the literature (Montgomery, 1999; Whiting and Bradley, 1993), emphasize the distinction between debris-flow and fluvial dominated valleys. Future studies should include debris-flow prone valleys to determine if they constitute a unique subset.

5. *What is the function of piped channels in the Np stream network?*

This question is important because piped channels are not presently be considered as “typed waters”. In 2001, piped channels were surveyed as part of the Np stream network with Ch, Pd and occasionally Pc being located within them. The literature on piped channels and macropores is growing. Piped channels are extremely important conduits of storm flow with the shallow pipes on hillslopes intercepting soil throughflow and conducting it a quickflow to the channel (Jones, 1997; Pearce and others, 1986; Ward, 1984). The subsurface erosion associated with pipe enlargement is main mechanism leading to gully formation [channel head extension] in an area where 70 percent of the stormflow is through piped channels (Swanson and others (1989). Ziemer (1992) noted that the larger pipes in the Caspar Creek Watershed in California maintained summer low flows in drainage basins around one hectare in size. Ground and soil levels in bedrock hollows may be controlled by the depth of macropores and piped channels (Montgomery and Dietrich, 1995) and thus serve an important slope stability function. Piped channels respond quickly to forest harvest the biological functions of piped channels have not been assessed.

Future studies could focus on the identification and functions of piped channels to assess their importance to FFR rules and their inclusion in the channel system during the assessment of the Np/Ns break

SECTION 6. SUMMARY

The pilot study confirmed that the pilot protocol was adequate to consistently collect channel data that could be used to identify the Np/Ns break (Pd). The protocol would be improved by requiring the continuous survey of the channel to the channel head.

The pilot study provides some useful insights on the character of headwater streams and default basin areas:

1. ***Perennial water is commonly located near the channel head***. The proximity of the channel head and Pd indicates that: 1) the channel head is a good indicator of perennial flow, and 2) the length of seasonal channel is very small relative to the length of perennial channels. This proximity produces a small basin area for Pd and requires the protocol to include the channel head in the survey.

2. ***Channel attributes do not change at Pd***. Changes in channel attributes, such as substrate or width, do not occur at the change from seasonal to perennial water (Pd) in any greater frequency than at other flow break within the stream. It is unlikely that physical attributes can be used to identify the Np/Ns break.

3. ***Observed basin areas for Pd are smaller than FFR default basin areas***: The results indicate that average observed basin areas are around 50% of the default basin areas and the median observed basin areas are less than 15% of the default basin areas. These results are similar to those from earlier studies in Washington.

4. ***The basin areas above Pd vary spatially across the state***. This variation is indicated by the differences between basin areas in different ecoregions and different FFR default regions. The preliminary analysis of this spatial variability as related to annual precipitation indicates that some measure of precipitation may control basin areas.

5. ***Distance from divide to Pd is less variable than basin area***. Although distance from divide to Pd is a function of the basin area above Pd, it is less variable as measured by the coefficient of variation. Its lower variability and greater ease of delineation than basin area makes it an attractive alternative indicator and potential default criterion.

6. ***Sample sizes required depend on the attribute of Pd that is being characterized -- basin area or distance from divide***. Sample sizes are the same for FFR default regions and precipitation classes but differ significantly between variable being measured. Sample sizes required to estimate distance from divide are only 10% of those for basin area.

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